

POLYETHYLENE TEREPHTHALATE RESIN CONTAINERTechnical Field

5 This invention relates to a container comprising a polyethylene terephthalate-based resin (hereinafter referred to as PET-based resin) and having an oxygen-capturing function and an oxygen barrier property, which have been improved by treating the container with radiation.

10 In the past, the PET-based resin containers have been utilized in various applications, including the fields of foods, drinks, and medicines, due to easy moldability and distinguished properties, such as transparency, chemical resistance, heat resistance, and mechanical strength, and have been used as the containers in which to fill those contents that have to be kept away  
15 from the contact with oxygen, including beer, fruit drinks, tea, coffee, and dips.

If the oxygen barrier property falls short in the containers using a PET-based resin alone, then the PET-based resin is blended with an oxygen barrier resin, such as an ethylene vinyl alcohol copolymer or a nylon resin, or an  
20 oxygen barrier layer is laminated with the PET-based resin layers.

Even if an oxygen barrier resin is laminated, as described above, to make the container usable, there still is oxygen in the air on and above the contents inside the container after it has been filled with the contents. Since  
25 this oxygen cannot be removed, there was no way to prevent the contents completely from coming in contact with oxygen and to avoid the oxidation of the contents. To cope with this problem, Official Gazette of Patent Application No. 1989-278344 discloses a multi-layered plastic container that enables oxygen to be captured by an intermediate layer, which is molded by a resinous  
30 composition containing a transition metal complex in an oxygen barrier resin.

However, the method disclosed in the above patent application 1989-278344 has some problems. Firstly, a high production cost is derived from the process for mixing a metal complex with the oxygen barrier resin. Secondly,  
35 moldability gets worse. Thirdly, the container has to be multi-layered because the metal complexes leach out and cannot be used for the surface with which the contents come in direct contact. Lastly, oxygen within the container cannot be fully captured because the layer having the oxygen-capturing function cannot be used as the inner layer.

This invention has been made to solve the above-described problems found in conventional art. The technical problem of this invention is to create an effective oxygen-capturing function even in the container made of a single PET-based resin layer, without adding to the resin such an ingredient as a metal complex. The object of this invention is to provide a PET-based resin container having the effective oxygen-capturing function and an improved level of oxygen barrier property.

#### Disclosure of the Invention

10

The means of carrying out the invention of Claim 1 to solve the above-described problems exists in the configuration that the container comprises a polyethylene terephthalate resin and has an oxygen-capturing property and an oxygen barrier property that have been improved by treating the container with radiation after the molding operation.

15

The polyethylene terephthalate resin(hereinafter referred to as PET resin)is mainly used as the PET-based resin in the container of this invention.

But as far as the nature of the PET-based resin is not impaired, copolymerized polyesters containing other polyester units can be used in addition to a major portion of ethylene terephthalate units. As the components that can be used in this invention to form a polyester copolymer, there may be mentioned dicarboxylic acid components, such as isophthalic acid, naphthalene-2,6-dicarboxylic acid, and adipic acid; and glycolic components, such as propylene glycol, 1,4-butane-diol, tetramethylene glycol, neopentyl glycol, cyclohexane dimethanol, and diethylene glycol.

20

25

The PET-based resin blended with another resin can be used within a limit in which the nature of the PET-based resin is not impaired. For example, polyethylene naphthalate (PEN) can be blended with the PET-based resin to improve heat resistance and chemical resistance, or a nylon resin can be blended to improve heat resistance and gas barrier property.

30

Those resins having the gas barrier property can also be used by laminating them with the PET-based resin within the limit in which the nature of the PET-based resin container is not impaired.

35

Amorphous PET-based resin can also be used as a PET-based resin. The amorphous PET-based resin has no melting peak when it is measured the melting temperature ( $T_m$ ) using a differential scanning calorimeter (DSC). An

40

example of amorphous PET-based resin is PETG of Eastman Chemical Company, which is obtained by copolymerizing PET-based with a glycol component, such as cyclohexane dimethanol.

5           Radiation, such as alpha ray, beta ray, gamma ray, X-ray, neutron radiation, and electron beam, can be used in this invention.

          Irradiation causes free radicals to be generated inside the PET-based resin. These radicals react with oxygen existing dissolved in the resin. As a  
10       result, the oxygen-capturing function is fulfilled.

          The above-described oxygen-capturing function serves to capture oxygen that dissolves into the container wall from outside and moves to the inside of the container. During the period in which this oxygen-capturing function is  
15       active, the transmission of oxygen from outside to the inside of the container is controlled. Thus, the irradiation improves the oxygen barrier property of the exposed container much more than that of the container to which no radiation has been applied.

20           On the other hand, since there is no need of adding such substances as a metal complex, an oxidation catalyst, or an oxidation initiator, to obtain the oxygen-capturing function, the layer having the oxygen-capturing function can be brought into direct contact with the contents. After the container has been filled with the contents and sealed, oxygen existing in the air above the  
25       contents inside the container and oxygen dissolved in the contents move into the container wall and react there with free radicals. In this manner, oxygen inside the container can be reduced effectively within a short period.

          The means of carrying out the invention of Claim 2 exists in the  
30       configuration that the container comprises a single layer of the PET-based resin specified in the invention of Claim 1.

          In the above configuration of Claim 2, even an ordinary single-layered PET-based resin container can be provided with the oxygen-capturing function  
35       by irradiating the container after it has been molded, without adding thereto such substances as a metal complex, an oxidation catalyst, and an oxygen initiator. For at least the period in which this oxygen-capturing function is maintained, the container keeps an improved level of oxygen barrier property.

The means of carrying out the invention of Claim 3 exists in the configuration that the container specified in the invention of Claim 1 has at least an inner layer and an outer layer, with both layers comprising the PET-based resin.

5

Multi-layered containers having an intermediate layer of a gas barrier resin are used to improve the gas barrier property. By the configuration of Claim 3, the inner and outer layers are made of the PET-based resin. Therefore, it becomes possible to retain distinguished properties of the PET-based resin, such as moldability, transparency, heat resistance, chemical resistance, and mechanical strength.

The means of carrying out the invention of Claim 4 exists in the configuration that the PET-based resin specified in the invention of Claim 1, 2, or 3 is blended with an oxygen barrier resin at a rate in the range of 1.0 to 30 wt.%.  
15

Any oxygen barrier resin, which is well known in the art, can be used, including nylon resins, such as nylon 6, nylon 66, and polyamide containing xylylene radicals; and an ethylene vinyl alcohol polymer.  
20

By the above-described configuration of Claim 4, the PET-based resin in use is blended with a resin having an oxygen barrier property. Since oxygen creeping in from outside can be inhibited to a lower level than when the PET-based resin is used alone, the free radicals generated by irradiation have fewer opportunities in which these radicals are diminished by the oxygen creeping in from outside. Therefore, the oxygen-capturing function continues to work for a longer period, and the oxygen barrier property is maintained at an improved level for a longer period, than the usual.  
25

30

The oxygen barrier resin is blended with the PET-based resin in a relatively small amount. Therefore, most of the oxygen barrier resin is not exposed to the outer or inner surface of the container, but is scattered inside the wall, and has little chance of coming in direct contact with oxygen existing inside and outside of the container. The oxygen-capturing function of the scattered oxygen barrier resin is maintained for an extended period, and thus the oxygen barrier property can be maintained at an improved level during that period.  
35

The oxygen barrier resin has usually an active radical of some kind, such as a double bond or a carbonyl radical. In many cases, irradiation tends to increase the frequency of radical generation, and therefore, improves the oxygen-capturing function of the container.

5

In this configuration, it is necessary for the oxygen barrier resin to be blended in an amount in the range of 1 to 30 wt.%. At a level less than 1%, the oxygen-capturing function would show only a minor level of improvement. Above 30%, the PET-based resin would lose its original moldability,

10 transparency, and mechanical strength.

The means of carrying out the invention of Claim 5 exists in the configuration that the oxygen barrier resin specified in the invention of Claim 4 is a polyxylylene diamine adipamide resin (Nylon-MXD6).

15

Due to the above-described configuration of Claim 5, Nylon-MXD6 resin has outstanding oxygen barrier property. Since Nylon-MXD6 has xylylene radicals on the main chain, this resin has a high oxygen-absorbing ability by nature. Furthermore, since Nylon-MXD6 tends to generate free radicals when it is exposed to radiation, the blend with the PET-based resin fully demonstrates the oxygen-capturing function.

20

The means of carrying out the invention of Claim 6 exists in the configuration that the container specified in the invention of Claim 1, 2, 3, 4, or 5 is treated with a radiation dose of 20 kGy or more.

25

Radiation of 20 kGy or more applied to the container can be remarkably effective in improving the oxygen barrier property. The larger the extent of irradiation, the more improved oxygen-capturing function is derived, but coloration may be caused disadvantageously. The upper limit to irradiation can be set suitably, depending on the color development of the resins, the purpose intended for the container, and the necessity.

30

The means of carrying out the invention of Claim 7 exists in the configuration that the container specified in the invention of Claim 1, 3, 4, or 5 has at least an intermediate layer comprising an oxygen barrier resin.

35

In the above-described configuration of Claim 7, the oxygen barrier property is greatly improved by the existence of an intermediate layer having the oxygen barrier property. Therefore, the invasion of the container by

40

outside oxygen can be inhibited dramatically. There are much fewer opportunities for the free radicals generated by irradiation to be consumed by the incoming outside oxygen. Even at a low dose of radiation, the oxygen-capturing function can be persistent for an extended period, and the oxygen  
5 barrier property is maintained at an improved level during that period.

The oxygen-capturing function of the oxygen barrier resin is maintained for an extended period because the intermediate layer comprising the oxygen barrier resin does not come in direct contact with the oxygen inside or outside  
10 of the container. This detached condition allows the oxygen barrier property to be maintained at an improved level during that period.

The means of carrying out the invention of Claim 8 exists in the configuration that the oxygen barrier resin of the container specified in the  
15 invention of Claim 7 is a polyxylylene diamine adipamide resin (Nylon-MXD6).

Nylon-MXD6 has an outstanding oxygen barrier property. Because this nylon has xylylene radicals on the main chain, free radicals tend to be generated by irradiation. If this nylon is laminated with a PET-based resin,  
20 then it is possible for the container to perform fully the oxygen-capturing function.

Nylon-MXD6 can be blended easily with the PET-based resin, or the container of a multi-layered structure can also be molded. In either way, a  
25 high level of productivity can be maintained for the container.

The means of carrying out the invention of Claim 9 exists in the configuration that a radiation dose of 6 kGy or more is applied to the container specified in the invention of Claim 7 or 8.  
30

The oxygen-capturing function is effectively performed by the container having an intermediate layer comprising an oxygen barrier resin. Even at a dose as small as 6 kGy, an improved effect of the oxygen barrier property is demonstrated.  
35

The means of carrying out the invention of Claim 10 exists in the configuration that an electron beam is used as the source of radiation in the invention of Claim 1, 2, 3, 4, 5, 6, 7, 8, or 9.

Any well-known electron irradiation equipment can be used industrially with relative ease.

### Brief Description of the Drawings

5

Fig. 1 is a graph showing time-lapsed changes in the oxygen-absorbing rates for the PET and Nylon-MXD6 resins after exposure to electron beam radiation.

Fig. 2 is a graph showing time-lapsed changes in the oxygen  
10 transmission rates for the PET-based resin containers of Examples 1 to 3.

### Preferred Embodiments of the Invention

This invention comprises applying radiation to the PET resin container  
15 from outside to generate free radicals, which imparts the oxygen-capturing function to the container and improves the oxygen barrier property. The action and effect and the actual configuration of this invention are further described below in examples.

20 Table 1 shows the results of the measurements using a PET resin and Nylon-MXD6 (T-600, Toyobo) as the oxygen barrier resin to evaluate the improvement in the oxygen-capturing function, which should be given by the exposure to radiation.

#### 25 • Method of measurement:

Electron irradiation equipment was used to apply doses of 20, 100, and 1,000 kGy to each type of the resin samples. The irradiated samples comprising 50 g of PET resin and 45 g of Nylon-MXD6 pellets were sealed in 50-ml sample bottles and kept at 22°C. The oxygen content of air inside the  
30 bottles was measured over time, and was expressed in the amount of oxygen that was absorbed in 1 g of resin (cc/g). Table 1 shows the values measured after 56 days, and also shows the results from unexposed resin samples.

Table 1. Oxygen Absorption Rates (cc/g)

	Unexposed	20 kGy	100 kGy	1,000 kGy
PET	0.0018	0.0090	0.0282	0.0421
MXD6	0.0067	0.0306	0.0514	0.0596

35

Fig. 1 shows the graph of variations over time in the oxygen absorption rates.

From Table 1 it is found that after electron irradiation, Nylon-MXD6 resin has a larger oxygen-absorbing ability than the PET resin has. It is also found that both resins show greatly improved oxygen absorption rates achieved solely by means of the electron irradiation without adding thereto a metal complex, an oxidation catalyst, or an oxidation initiator, or without modifying the resins.

Fig. 1 shows that the oxygen-absorbing function remains active for about 30 days in the unexposed samples of the PET resin and the PET resin samples irradiated at doses of 20, 100, and 1,000 kGy and the unexposed samples of Nylon-MXD6 and the Nylon-MXD6 samples irradiated at a dose of 20 kGy. Furthermore, it is also found that oxygen absorption continues to work after 50 days in the samples of Nylon-MXD6 irradiated at doses of 100 and 1,000 kGy.

This invention is now described by the examples using 3 types of containers. In Example 1, the PET resin bottle used in the measurement was obtained by the biaxial drawing and blow-molding method. In Example 2, the bottle was obtained by using a biaxial extruder to blend 4 wt.% Nylon-MXD6 with the PET resin, and then biaxially drawing and blow-molding the blended material. In Example 3, the multi-layered bottle was obtained by biaxially drawing and blow-molding the multi-layers comprising PET resin (inner layer) – Nylon-MXD6 resin – PET resin (outer layer). These bottles were fixed on the rotary irradiation jigs, and were rotated while electron beams were irradiated, using well-known electron irradiation equipment. The Nylon-MXD6 resin laminated in Example 3 had a proportion of 5 wt.%.

After irradiation, each bottle was measured for its oxygen gas transmission rate over time. Table 2 shows the transmission rates measured after certain periods of days. Fig. 2 is a graph showing the changes in the transmission rates over time.

• Test conditions:

1) Bottle: A capacity of 300 ml; an average body wall thickness of 0.35 mm

2) Method of transmission rate measurement:

Measuring device: MOCON Ox-Tran, 22°C – 55%RH, unit in cc/(day-bottle)



Table 2. Oxygen Transmission Rate (cc/(day-bottle))

		Lapsed days	Electron irradiation dose			
			No exposure	20 kGy	100 kGy	1,000 kGy
Example 1	Single PET	After 20 days	0.021	0.021	0.019	0.020
Example 2	MXD6 blend	After 40 days	0.013	0.012	0.012	0.0032
Example 3	MXD6 laminate	After 40 days	0.004	-	0.0008	-

Fig. 2 shows that concerning the bottle of Example 1 comprising a single layer of PET resin, the larger the irradiation is, the lower oxygen transmission rate is derived in the initial period of the test. In about 20 days, transmission was saturated, and the transmission rate came up to the same level as unexposed bottle. This behavior corresponded to the changes over time in the oxygen absorption rate of the PET resin. During the initial period, it is suspected that the oxygen transmission rate stays at a low level because of the oxygen absorption.

Thus, even the single-layered PET resin bottle is found to demonstrate the oxygen-capturing effect in- and outside of the container, managing the oxygen transmission rate to be kept at a low level for at least 20 days. Therefore, the exposed single-layered bottle can be effectively utilized in applications having relatively short shell lives.

The unexposed bottle of Example 2 comprising a single layer of PET blended with Nylon-MXD6 shows a considerably lower oxygen transmission rate than the bottle of single-layered PET alone because of the blending effect. As found from Fig. 2, the electron beam irradiation gave far lower rates. With a radiation dose of 1,000 kGy, the low transmission rate is fully demonstrated even after 50 days. This result can be understood reasonably from the time-lapsed changes in the oxygen absorption rates shown in Fig. 1.

Due to the lamination effect, the multi-layered bottle of Example 3 comprising also Nylon-MXD6 shows an oxygen transmission rate about 1/5 as low as that of the single-layered bottle of PET alone under the unexposed condition. As found from Fig. 2, the electron beam irradiation improved the oxygen barrier property so as to extend the effective duration for about 10 days at a dose as low as 6 kGy. A dose of 100 kGy allowed the container to have a transmission rate about 1/2 as low as found in the unexposed bottle after 50 days. In addition, since the Nylon-MXD6 layer serves as a large barrier and stands against oxygen that invades from outside the bottle, it is believed that the effect of lamination continues for an extended period even when the bottle has been irradiated at a low dose.

It was thus found that with no addition of a metal complex, an oxidation catalyst, or an oxidation initiator, the electron beam irradiation onto the PET resin container simply gave the container the oxygen-capturing function and greatly improved the oxygen barrier property. The duration of improved oxygen barrier may differ, depending on whether the body wall consists of a single layer of PET resin, a blended layer comprising an oxygen barrier resin, or laminated layers.

With considering the intended use and the shelf lives the most suitable container wall can be selected from among these types.

In Example 3, this invention was described by taking up a multi-layered bottle having a structure comprising PET resin (inner layer) – Nylon-MXD6 – PET resin (outer layer). It should be understood that the laminate structure of the multi-layered container is not limited to this Example. In Example 3, for instance, use can be made of a container having an adhesive layer to adhere the PET resin to the Nylon-MXD6 resin, or a container having an intermediate layer comprising the PET resin blended with a small amount of Nylon-MXD6. Indeed, any combination of various layers can be used for any purpose as far as the nature of the PET resin container is retained. The oxygen barrier resin to be selected for this invention is also not limited to the Nylon-MXD6 resin that has been taken up in Examples 2 and 3.

#### Effect of Invention

This invention having the above-described configuration has the following effects: In the invention of Claim 1, the radiation applied to the container simply creates free radicals within the PET-based resin, thus giving the oxygen-capturing function to the container. As a result, oxygen is prevented from transmitting from outside to the inside of the container for the period in which this oxygen-capturing function remains active. So irradiation improves the oxygen barrier property of the container better than that of the unexposed container.

There is no need to add, among others, any metal complex, oxidation catalyst, or oxidation initiator. The contents can be brought to direct contact with the inner wall of the container. Oxygen existing inside the container can be reduced effectively in a short period of time.

In the invention of Claim 2, the ordinary single-layered PET-based resin container can be given an oxygen-capturing function and an improved oxygen barrier property and can be used in a wide range of applications, simply when radiation is applied to the container without adding any metal complex,  
5 oxidation catalyst, and oxidation initiator.

In the invention of Claim 3, both the inner and outer layers are made of a PET-based resin. Thus, the container retains outstanding properties, such as moldability, transparency, heat resistance, chemical resistance, and  
10 mechanical strength, which the PET-based resin has.

In the invention of Claim 4, a small amount of a resin having the oxygen barrier property is blended with the PET-based resin. The use of such a blend allows the container to keep oxygen transmission from outside at a low level.  
15 As a result, free radicals generated by irradiation have fewer opportunities to disappear. The oxygen-capturing function continues to work for a further extended period, and the oxygen barrier property remains in the improved state during that period.

20 In many cases, oxygen barrier resins generally tend to generate free radicals when the resins are exposed to radiation. These resins themselves come to have an improved oxygen-capturing function, due to irradiation. On the whole, the container is led to acquire further improved levels of oxygen-capturing function and oxygen barrier property.

25 In the invention of Claim 5, the Nylon-MXD6 resin has an excellent oxygen barrier property. Since this resin has xylylene radicals on the main chain, free radicals tend to be generated when the resin is exposed to radiation. The container can fully demonstrate a high oxygen-capturing function if the  
30 PET-based resin is blended with Nylon-MXD6.

In the invention of Claim 6, the oxygen barrier property is greatly improved when the container is exposed to a radiation dose of 20 kGy or more.

35 In the invention of Claim 7, the container acquires an improved oxygen barrier property because this container has an intermediate layer comprising an oxygen barrier resin. Thus, it is possible to control the penetration of outside oxygen at a strikingly low level. As a result, free radicals generated by irradiation have far fewer opportunities in which the radicals are diminished  
40 by oxygen creeping in from outside. In that case, even a small radiation dose

is enough to keep the oxygen-capturing function working for a longer period than the usual, and the oxygen barrier property is maintained at an improved level during that period,.

5           The intermediate layer comprising an oxygen barrier resin does not come in direct contact with oxygen inside or outside of the container. Owing to this lack of contact, the oxygen-capturing function continues to work for a more extended period than usual, and the oxygen barrier property is maintained at an improved level during that period.

10

          In the invention of Claim 8, Nylon-MXD6 has an outstanding oxygen barrier property. Because this nylon has xylylene radicals on the main chain, free radicals tend to be generated by irradiation. If this nylon is laminated with a PET-based resin, it is possible for the container to perform the full  
15 oxygen-capturing function.

20

          Nylon-MXD6 can be blended easily with the PET-based resin, and the container of a multi-layered structure can also be molded. In either way, highly productive containers can be obtained.

          In the invention of Claim 9, the oxygen-capturing function is effectively performed by the container having an intermediate layer comprising an oxygen barrier resin. Even at a dose as small as 6 kGy, an improved effect of the oxygen barrier property is demonstrated.

25

          In the invention of Claim 10, any well-known electron irradiation equipment can be used industrially with relative ease.